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Fishes from Lake Yaxhá, Mayan Biosphere Reserve, Petén, Guatemala

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Abstract: The Mayan Biosphere Reserve is the largest protected area in Guatemala. Lake Yaxhá is located inside the core zone. Using electrofishing, seines and gillnets we assessed the fish richness and community in 2011. We collected 18 species distributed in seven families, with Cichlidae (seven species) and Poecilidae (five species) the most specious. We evaluated the effectiveness of electrofishing to sample the most important fish in the artisanal fishery in Petén, *Petenia splendida*, with September being the month with the highest capture per unit of effort. Lake Yaxhá assemblage was similar to the Usumacinta through a hierarchical cluster analysis, despite being located in the Mopan-Hondo basin. Lake Yaxhá is the only system in the area that does not have non-native fish species, emphasizing the importance of conservation of this lentic system in the Mayan Biosphere Reserve.

Key words: ichthyofauna, Central America, Mayan Biosphere Reserve, electrofishing, artisanal fishery

INTRODUCTION

The northernmost department in Guatemala, Petén contains the Mayan Biosphere Reserve (MBR), the largest protected area in the country and combined with areas from México and Belize the most important tropical forest area in Mesoamerica (Regalado et al. 2012). Within the MBR different lotic and lentic aquatic systems are protected. Lake Yaxhá is the largest lake inside the core zone of the MBR and it has the lowest fishing pressure in the country (Barrientos C. personal observation). Lack of development and access in the north part of Guatemala contributed to make the artisanal-subsistence fishery one of the most important sources of livelihoods in the zone. Systems like Yaxhá, with minimal habitat transformation are exceptional difficult to come across (Valdez-Moreno et al. 2005; Granados-Dieseldorff et al. 2012). However, the large human population growth in Guatemala happened in this part of the country as part of the government developmental plans for Petén (Schwartz 1990). The MBR is under significant anthropogenic pressure with colonization, deforestation and other associated impacts. It is just a matter of time before impacts manifest themselves.

The ichthyofauna in the north part of Guatemala represents approximately 25% of the highly diverse continental fish fauna of Guatemala (Kihn et al. 2006). Several researches have worked in the area since 1800's, so it is considered to be a well-known ichthyofauna (Willink et al. 2000; Valdez-Moreno et al. 2005). Most of the ichthyological studies in the Lake Yaxhá are more than 40 years old (Miller 1966). We did not find a specific collection for the lake and the most recent inventories in the region have not included Lake Yaxhá (Valdez-Moreno et al. 2005).

Petén is located in the southern extent of the Yucatan Peninsula a large marine limestone platform and possesses a lake district comprised of about 14 large waterbodies, of which Lake Yaxhá is the second largest (~22 km^2) (Figure 1). This zone shows the typical karst topography; hosts numerous lakes that have been thoroughly studied because of rich sediments (Deevey et al. 1980; Leyden 1987). Most of the lakes in this zone were formed by dissolution. The presence of rivers is not important for the lakes in this zone, because basins in the Lake District are usually closed. The lake water

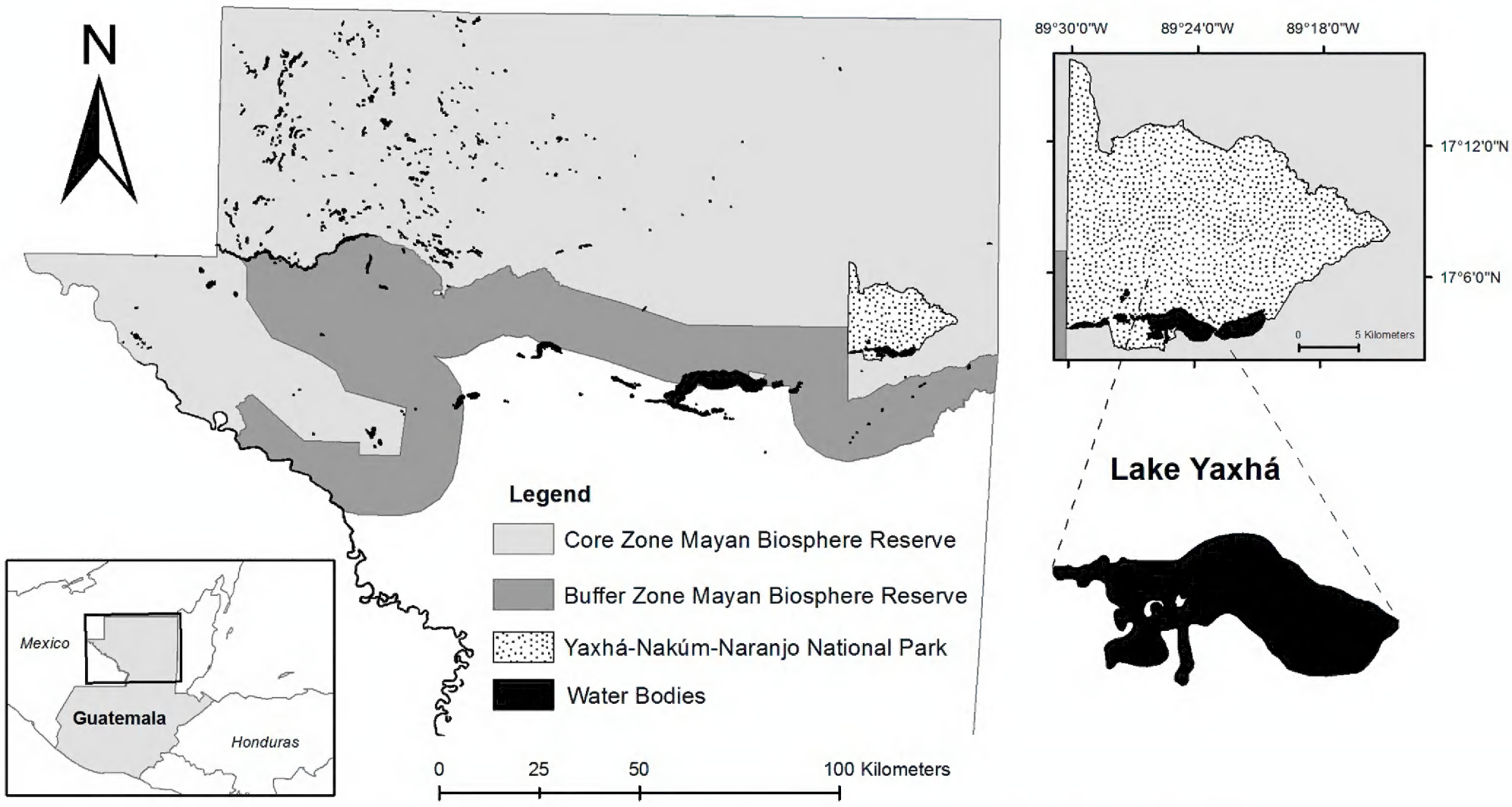

Figure 1. Lake Yaxhá study area located in Yaxhá-Nakún-Naranjo-National Park, Mayan Biosphere Reserve, Petén, Guatemala.

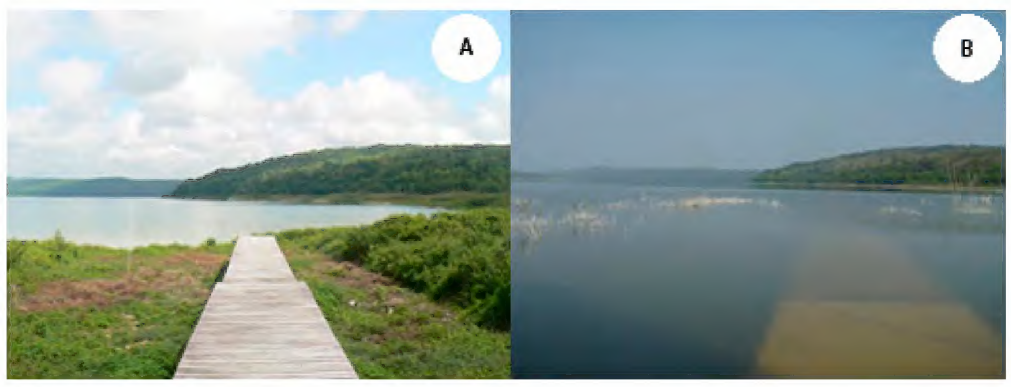

Figure 2. View from the CONAP camp deck before and after the 75 cm change of Lake Yaxhá levels in September 2011.

chemical composition is dominated by cations Ca and Mg and anions SO_4, HCO_3 (Perez et al. 2011). The levels in these lakes can rapidly change (Figure 2), as a direct consequence of climate fluctuations (Deevey et al. 1980).

The aquatic vegetation in Petén has been studied in lakes and rivers. Leon and Morales (2000) reported eight species of submerged vegetation in the eastern region of the MBR, at Laguna del Tigre National Park.

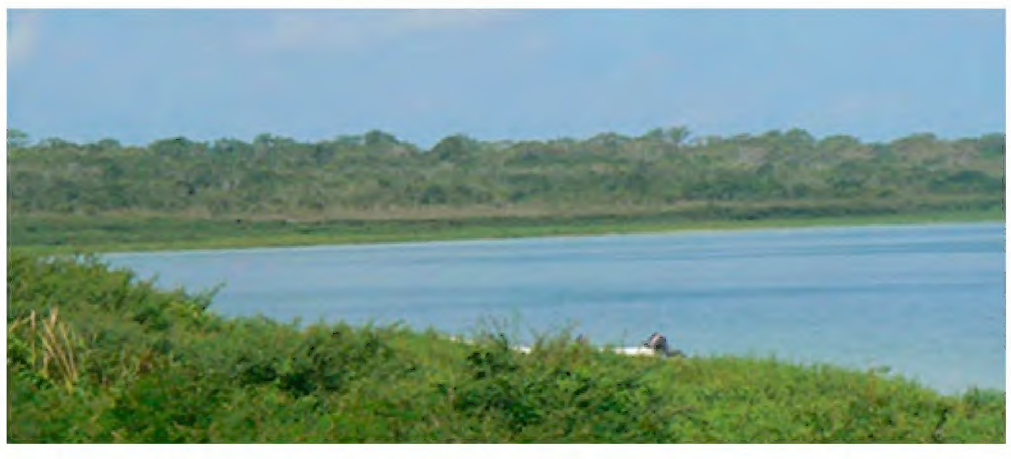

Figure 3. View of Lake Yaxhá riparian forest cover in 2011 showing the littoral zone.

Reyes (2009) compared aquatic vegetation present in lakes and lagoons in the Tikal-Yaxhá region and reported *Vallisneria americana* Michx and *Potamogeton illinoiensis* (Morong) as dominant species when human activities modify water nutrients in the lakes. Lake Yaxhá has riparian forest in the littoral zone with *Haematoxylum campechianun*, *Bucida burceras* and *Pachira acuatica* and some species of Cyperaceae as well (Figure 3). Within the water we found several different submerged plants, but the low transparency of the water precludes the widespread distribution and abundance of submerged vegetation. Instead we have a large zone with the presence of *Mimosa pigra*. Because of the changing levels of the lake, *Mimosa pigra* can be dead but the branches beneath the water created submerged structure used as habitat by many fishes (Figure 4).

The ichthyological history of the Petén area started with collections from European researchers in the early 1800s and continues with North American researchers in the 1900s. For a detailed history of ichthyological expeditions see Kihn et al. (2006). The most recent fish species list for Petén area was compiled by Valdez-Moreno et al. (2005). Recently, Barrientos and Quintana (2012) assessed the littoral zone habitat as a part of a general impact of exotic species in Guatemalan lakes. They reported 19 species present in Lake Petén Itzá, west of Lake Yaxhá. Brenner et al. (2002) mentioned that a non-published list compiled from collections by Bailey and Rosen during the 1960s with 22 species for five different lakes, all clumped together, that included Petén Itzá, Macanche, Salpeten, Yaxhá and Sacnab.

Figure 4. *Mimosa pigra* cover before (A) and after (B) lake water fluctuation in 2011 (~ 75 cm).

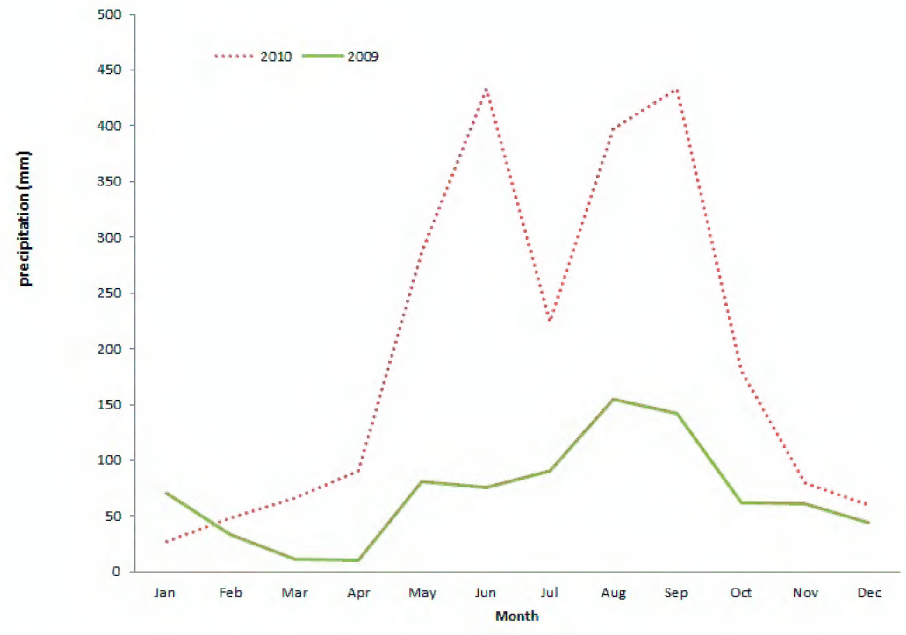

Figure 5. Average monthly rainfall (mm) in Petén, Guatemala in 2009 (solid line) and 2010 (dotted line). Data from INSIVUMEH, Guatemala.

Since Lake Yaxhá has no specific collection of fishes in any of the national museums or inter-institutional databases, we sampled Lake Yaxhá in March to October 2011. The main goal was to develop a current list of ichthyofauna in the system, compare different season's richness and assess the usefulness of electrofishing to estimated capture per unit of effort for the most important fish in artisanal fishery in Petén, bay snook (*Petenia splendida*). This data will be used by the National Council of Protected Areas and the National Fisheries Authority that manage fisheries in Petén including Lake Yaxhá.

Materials and Methods

Since 1991 the MBR has been a protected area in Guatemala. The MBR has been recognized as the largest tropical rainforest in Guatemala (Regalado et al. 2012), and forms the third largest tropical forest of the Americas, shared with México and Belize, which have protected areas in adjacent zones as well. The National Park of Yaxhá-Nakum-Naranjo is located in the core zone of the MBR. It was established in 2003 (Decreto 55-2003) and was later included in the Annotated Ramsar List of Wetlands of International Importance since 2006 (Ramsar 2012). The Yaxhá National Park is the second most visited archeological site in Guatemala only behind Tikal National Park (INGUAT 2010).

Lake Yaxhá is located in Petén central lacustrine zone part of the Mopan River basin (17°09′N, 089°25′ W), in the south part of the Yaxhá-Nakum-Naranjo National Park. Lake Yaxhá has a surface area of 22 km² with a maximum depth of 27 m and a ~170 m above sea level. Access to the Lake is limited to ~15 km of non-paved road, which restricts vehicle visits in the rainy season to those with four-wheel drive. Within the lake, there are only a few small artisanal boats used for transportation to the archeological site Topoxte. Fishing and hunting is prohibited. National Council of Protected Areas (Consejo Nacional de Areas Protegidas; CONAP) and Institute of Anthropology and History (Instituto de Antropologia e Historia; IDAEH) share the park administration. Eutrophication does not play a large role in this lake. Only a few farms are located along the south basin of Lake Yaxhá.

The National Institute of Hydrology (Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología; INSIVUMEH) records temperature and precipitation. The climate in this zone is characterized by strong precipitation from May to October (Figure 5). The lowest average environmental temperature was 21°C in January and the highest 30°C in May. The lake is a closed basin with no visible outlet and exhibits water fluctuations that usually correlates with precipitation, similar to other lakes in the area.

Fish were collected using different fishing gears, however electrofishing was the main gear used in the littoral zone around the lake. Initially we sampled the complete shoreline, except for some sites where our boat could not maneuver among the logs and dead bushes. Lake Yaxhá has a high degree of steepness along the north shore and the littoral zone along the south shore had a high amount of logs and vegetation debris. In March 2011, we used gillnets and seines with less success than electrofishing. Experimental gillnets were between 100–200 m long and 2.5 m high of stretch monofilament with different mesh size (3, 5, and 7 cm). Soak times were from sunset to sunrise (8–10 h), usually moved a couple times during the night. Gillnets were set parallel to the shoreline where depth permitted. Because of the high density of crocodiles (F. Castaneda personal comment) we checked the nets every 2–3 h. We used seines in areas where we could manage to work with them, but because of the large amount of vegetation debris and logs it was the less successful gear. Electrofishing was implemented with a boat-mounted electrofisher (1.5 KVA; Smith-Root, Vancouver, Washington) with a single cathode in the front of the vessel. The electrical output ranged was 6–9 A of pulsed DC. We sampled the littoral zones for at least 1 hour divided in 5–6 parallel transects to the shoreline with a total length range of 700–1,100 m, once a month from March to October 2011.

All specimens were identified to the lowest taxonomic group using the key for continental waters of Belize from Greenfield and Thomerson (1997) and original descriptions for some specific groups. We arranged

and used names for the taxonomic list according to Eschmeyer (2015). Voucher specimens were deposited in the fish collection of the Museo de Historia Natural (MUSHNAT) (Table 1), Universidad de San Carlos de Guatemala (USAC), Guatemala City. Research (Investigacion No.366-A) and collection (Colecta No.12703) permits were granted by CONAP. We estimated biomass as a mean weight of the fish captured in all transects (n = 6–10) made in March and September.

Although we used all gears in March 2011, for the analysis we only used electrofishing samples. We sampled three main zones around the lake. First zone is known as "El arroyo", that is in the southern part of the lake, just to the west of the archeological site "Topoxte". The second site was at the eastern part of the lake "El Juleque" and the third one was close to the permanent site of IDAEH facilities. Because of fluctuating water levels during our sampling, some of the zones were not available during some months, thus samples were not always in these three sites.

We compared the fish from Lake Yaxhá to other systems in same biogeographic region using a hierarchical cluster analysis to examine patterns of similarity in species presence and absence between different sites. We used R Ver. 3.0.1 (http://www.r-project.com) with the community ecology package- vegan (Osaken et al. 2015) with the average linkage method to construct the hierarchical cluster analysis. We included fishes from Lake Petén Itzá (Barrientos and Quintana 2012), Lake Lachua (Granados-Dieseldorff et al. 2012), Laguna del Tigre National Park (Willink et al. 2000) in Guatemala; Lacanja River (Rodiles-Hernández et al. 1999) and Lagunas de Metzabok/Lacandona (Vallejo 2011) in México and Monkey River divided in three zones in Belize (Esselman et al. 2006).

RESULTS AND DISCUSSION

We sampled 1,695 fishes, representing 18 species and seven families in the Lake Yaxhá (Table 1). Similar to other studies in the north part of Guatemala, Cichlidae is the dominant family with 41% of all species present (Willink et al. 2000; Valdez-Moreno et al.2005; Barrientos and Allen 2008; Quintana and Barrientos 2011; Barrientos and Quintana 2012; Granados-Dieseldorff et al. 2012), which agrees with the general trends of the Usumacinta Province (Miller 1966). Cichlids show a high diversity in ecology, morphology and behavior in the neotropics (Winemiller 1995). Cichlids can specialize in the use of all kind of resources, from algae to fishes, which probably explain why they are the dominant family in the Usumacinta province (Cochran and Winemiller 2010). Cichlids have seven species and represent 90% of the biomass present at the lake in our sampling, occupying all habitats present in the littoral zone at Lake Yaxhá. Two species of cichlids, *Paraneetroplus melanurus* (Günther 1862) and *Petenia splendida* Günther 1862 accounted for more than 80% of the biomass and these are the two main species sought in the artisanal

Table 1. Mean and standard error biomass of 18 fish species collected in Lake Yaxhá during March and September of 2011. Gear: E= electrofishing, G= gillnets, S=Seines. MUSHNAT = Catalog collection number at Museo de Historia Natural de Guatemala.

Species	March	September	Gear	MUSHNAT
Clupeidae				
Dorosoma petenense (Günther, 1867)	1.8±0.8	2.2±1.8	E, G	2273
Characidae				
Astyanax aeneus (Günther, 1860)	43.1 ±14	6.1±1.7	E, S	2270
Hyphessobrycon compressus (Meek, 1904)	2.1 ±1.2	1.4±1	E, S	2268
Heptapteridae				
Rhamdia quelen (Quoy & Gaimard, 1824)		3.8±2	E	2283
Poeciliidae				
Belonesox belizanus Kner, 1860	3.5 ± 0.9		E	2269
Gambusia yucatana Regan, 1914	1.4 ± 0.2	0.9 ± 0.7	E	2281
Gambusia sexradiata Hubbs, 1936	0.2 ± 0.1		E, S	2280
Poecilia mexicana Steindachner, 1863	47.2±9.1	202.9±14.5	E, S	2275
Poecilia petenensis Günther, 1866	1±0.7		E, S	2274
Atherinopsidae				
Atherinella alvarezi (Díaz-Pardo, 1972)	43.1 ± 4	3±2.1	E, S	2272
Synbranchidae				
Ophisternon aenigmaticum Rosen & Greenwood, 1976	8.9±6.2		E	2285
Cichlidae				
Amphilophus robertsoni (Regan, 1905)	6.3 ± 3.2	0.6±0.9	E, S, G	2271
Cichlasoma salvini (Günther, 1862)	76. ±32	14.9±3	E, G	2265
Cichlasoma urophthalmus (Günther, 1862)	93.3±21	50.5±7	E, S, G	2267
Rocio octofasciata (Regan ,1903)		8.6	E	2286
Paraneetroplus melanurus (Günther ,1862)	1144.1±112	949.7±321	E, S, G	2276
Petenia splendida Günther, 1862	1192.9±37.5	1242.1±25.9	E, G	2277
Thorichthys affinis (Günther ,1862)	222.7±531	94.6±32.6	E, S, G	2266

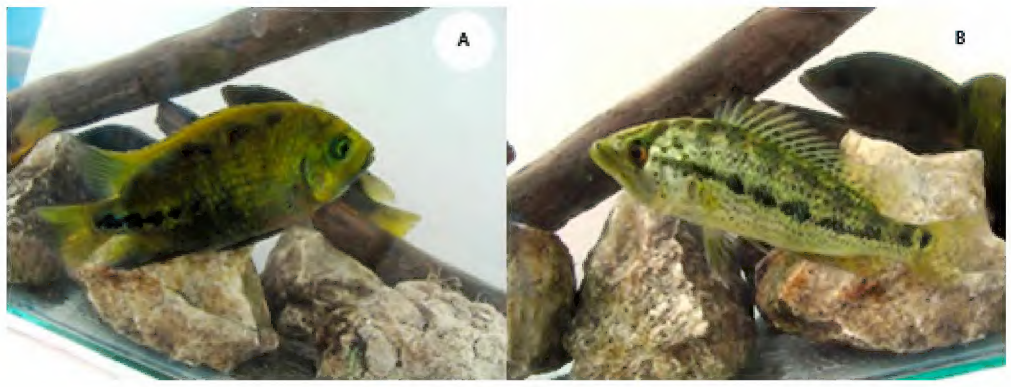

Figure 6. (A) *Paraneetroplus melanurus* and (B) *Petenia splendida* represented more than 80% of the biomass of fishes collected in Lake Yaxhá.

fisheries in Petén (Figure 6). Another well represented family is the Poeciliidae with five species. Some species like *Rocio octofasciata* (Regan 1903), *Ophisternon aenigmaticum* Rosen & Greenwood 1976 and *Rhamdia quelen* (Quoy&Gaimard 1824) were only captured in one sampling event and only a few individuals.

The fish assemblage in Lake Yaxhá was similar to Lake Petén Itzá, despite the area (Yaxhá ~5 times smaller), depth, and watershed differences between the lakes (Figure 7). We only found that there are four species not shared between the two lakes; two of those were the non-native *Oreochromis niloticus* (Linnaeus) and *Pterygoplichthys pardalis* (Castelnau 1855) only present in Lake Petén Itzá. The only native that is exclusive to Lake Yaxhá was *Rocio octofasciata* and the only exclusive native species to Lake Petén Itzá was *Parachromis friedrichsthalii* (Heckel 1840) (Barrientos and Quintana 2012). Both lakes have no major river that probably explains the lack of estuarine fishes (Granados-Dieseldorff et al. 2012). Brenner et al. (2002) reported 22 species that Bailey and Rosen collected in the 1960s in five lakes in the north Petén area, including Lake Yaxhá. We did not find all the species reported by them because it included four more lakes; however most of the species are present in Lake Yaxhá.

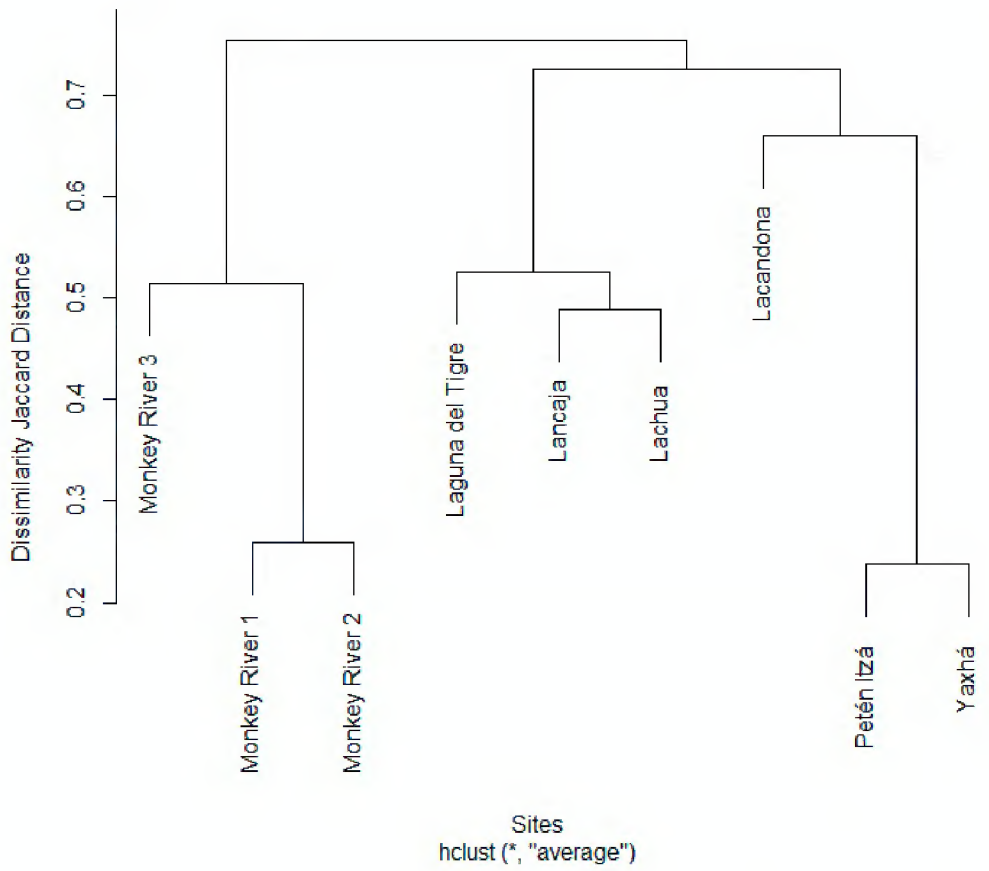

Figure 7. Dendrogram of the hierarchical cluster analysis classifying fish assemblages from systems in the south part of the Yucatan Peninsula; Lake Lachuá, Lacanja River, Laguna del Tigre National Park, Lake Petén Itzá, Lake Yaxhá and 3 different sections of Monkey River.

The similarity between Petén Itzá and Yaxhá was the greatest because species composition was almost the same (Figure 7). This was expected because lentic systems that have similar ecological attributes and located in the same ichthyological province share similar biological communities as well (Winemiller et al. 2011; Granados-Dieseldorff et al. 2012), despite Lake Yaxhá being part of the Mopan basin and Lake Petén Itzá located in the Usumacinta basin. The other sites grouped together were Laguna del Tigre National Park, Lacanja River and, Lake Lachua, with similar species composition. Nonetheless, Lake Lachua, was in our analysis convened with the rivers. This is probably because Lachua is connected with rivers that are part of the Usumacinta system; which allows several species from marine origin to access Lachua (Granados-Dieseldorff et al. 2012). Despite the fact that Lachua is five times smaller than Yaxhá it has more than double the number of species, probably because of the open connection to the Usumacinta river. Interestingly fishes from Belize Monkey River were separate because they are not contained in the Usumacinta basin (Figure 7). Lagunas de Metzabok/Lacandona was grouped with the lakes in Petén, probably because of the low number of species present in that system in Mexico.

Two species account for more than 80% of the biomass in Lake Yaxhá. *Petenia splendida* showed a similar electrofishing CPUE in all months, except in September (Figure 8). Higher CPUE was related to the second precipitation pattern, this change the lake water level, which probably allows *Petenia splendida* access into littoral sites otherwise inaccessible because of the low water level. Electrofishing has not been an effective gear in cichlid sampling in other tropical systems (Neal et al. 2006), at least when compared to fishes from the Centrarchidae family. *Petenia splendida* is endemic to the ichthyological Usumacinta province and to our

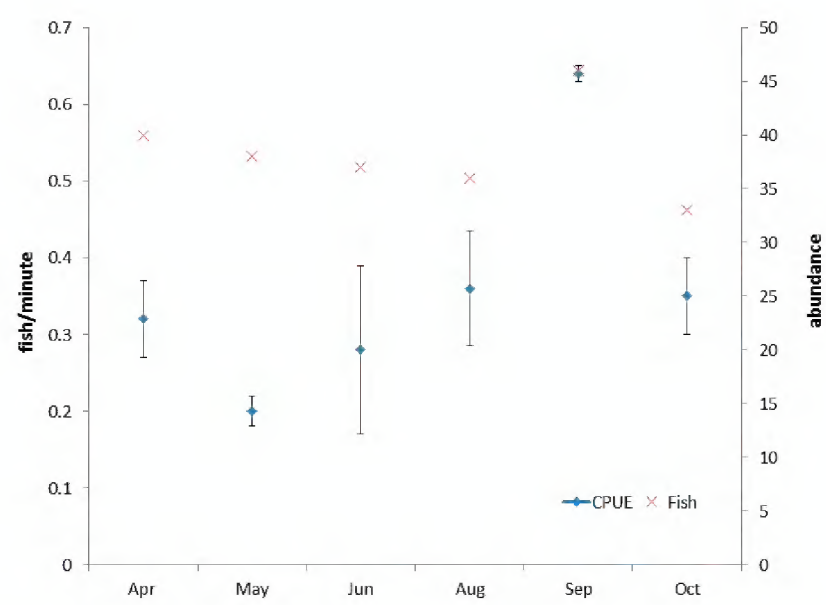

Figure 8. *Petenia splendida* catch per unit of effort (CPUE) in different months at Lake Yaxhá. Bars represent standard error. Secondary axis shows the total number of fish captured each month during 2011.

knowledge this the first time using electrofishing to sample this species in lentic systems, thus there is no real comparison to other systems. However just using gill nets and seines for the same amount of time we did not even reach 10% of our capture with electrofishing. We believed that this shows that electrofishing can be successfully used to sample *Petenia splendida* in littoral habitats at Lake Yaxhá and the north part of Guatemala with similar water quality characteristics.

Seasonal differences were low, which is surprising, because data from other systems in Guatemala show a low abundance in rainy season (Quintana and Barrientos 2011; Barrientos and Quintana 2012). Moreover, CPUE for *Petenia splendida* was high in September (Figure 8), which is still part of the rainy season. Some species were only captured during the rainy season, like *Rocio octofasciata* and *Rhamdia quelen*. Despite the presence of two exotic species in Lake Petén Itzá, which is relatively nearby, we did not found any exotic species in Lake Yaxhá. Considering the widespread invasion of tilapias in adjacent areas (Willink et al. 2000; Valdez-Moreno et al. 2005; Barrientos and Quintana 2012) it is surprising that they are not present in Lake Yaxhá. Moreover the highly invasive *Pterygoplichthys pardalis* (Castelnau 1855) is found in almost in every river connected to the Usumacinta (Wakida-Kusunoki et al. 2007) and recently in Lake Petén Itzá (Barrientos and Quintana 2012), but not in Lake Yaxhá. This is something that the Yaxhá Park managers want to safeguard. Several systems in Guatemala have intensive human impacts; however Lake Yaxhá is one of the few examples of lakes with minimal impact in the basin, moreover almost no artisanal fishery was present at the lake at the sampling time. We advocate maintaining the regulation and conservation in the area in order to manage the aquatic resources in the north part of Guatemala.

ACKNOWLEDGEMENTS

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